Why were some La Ninas followed by another La Nina?

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(Also discussed with Fei-Fei Jin, Michelle Lheureux, and Wanqiu Wang)

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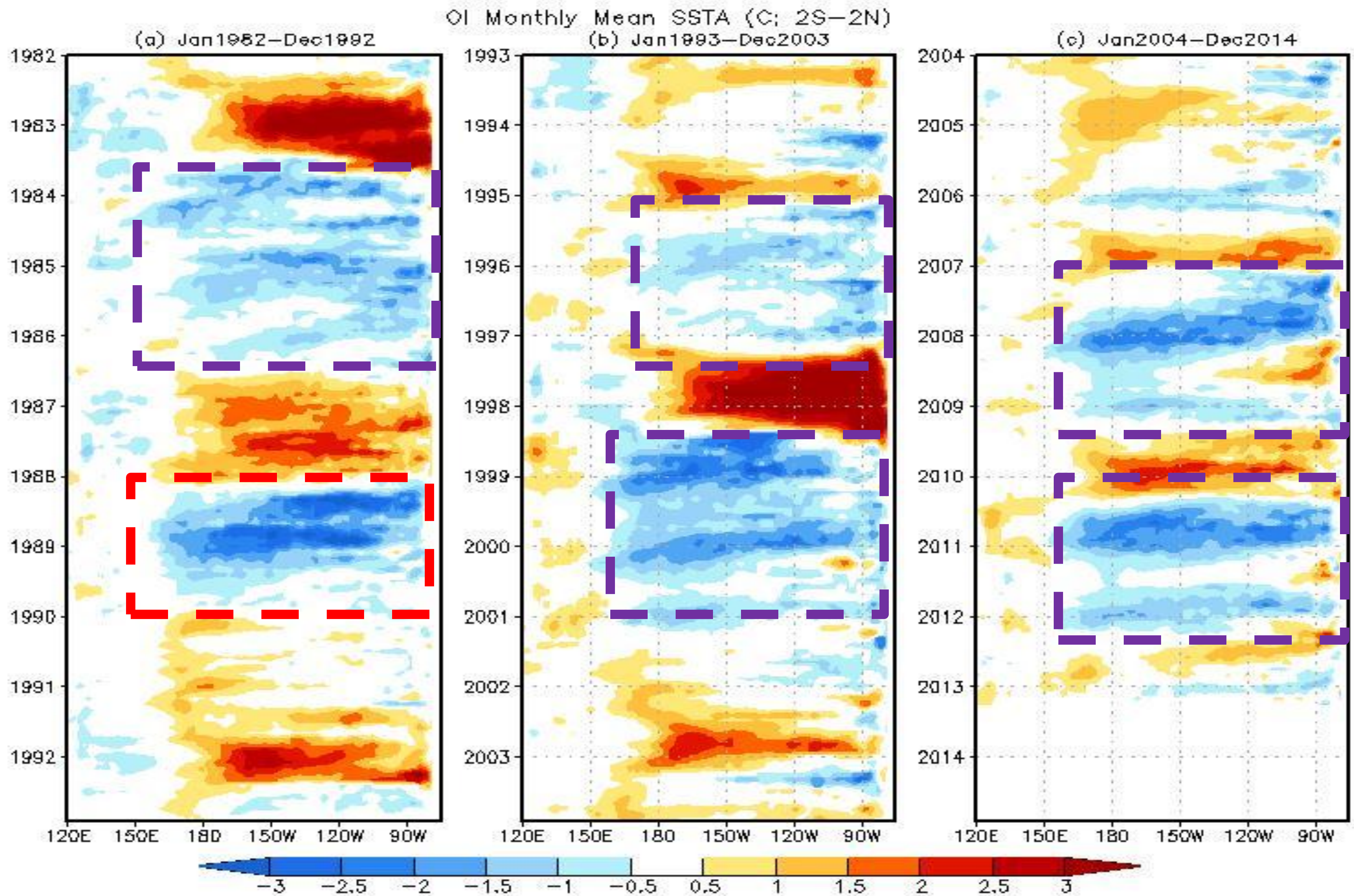
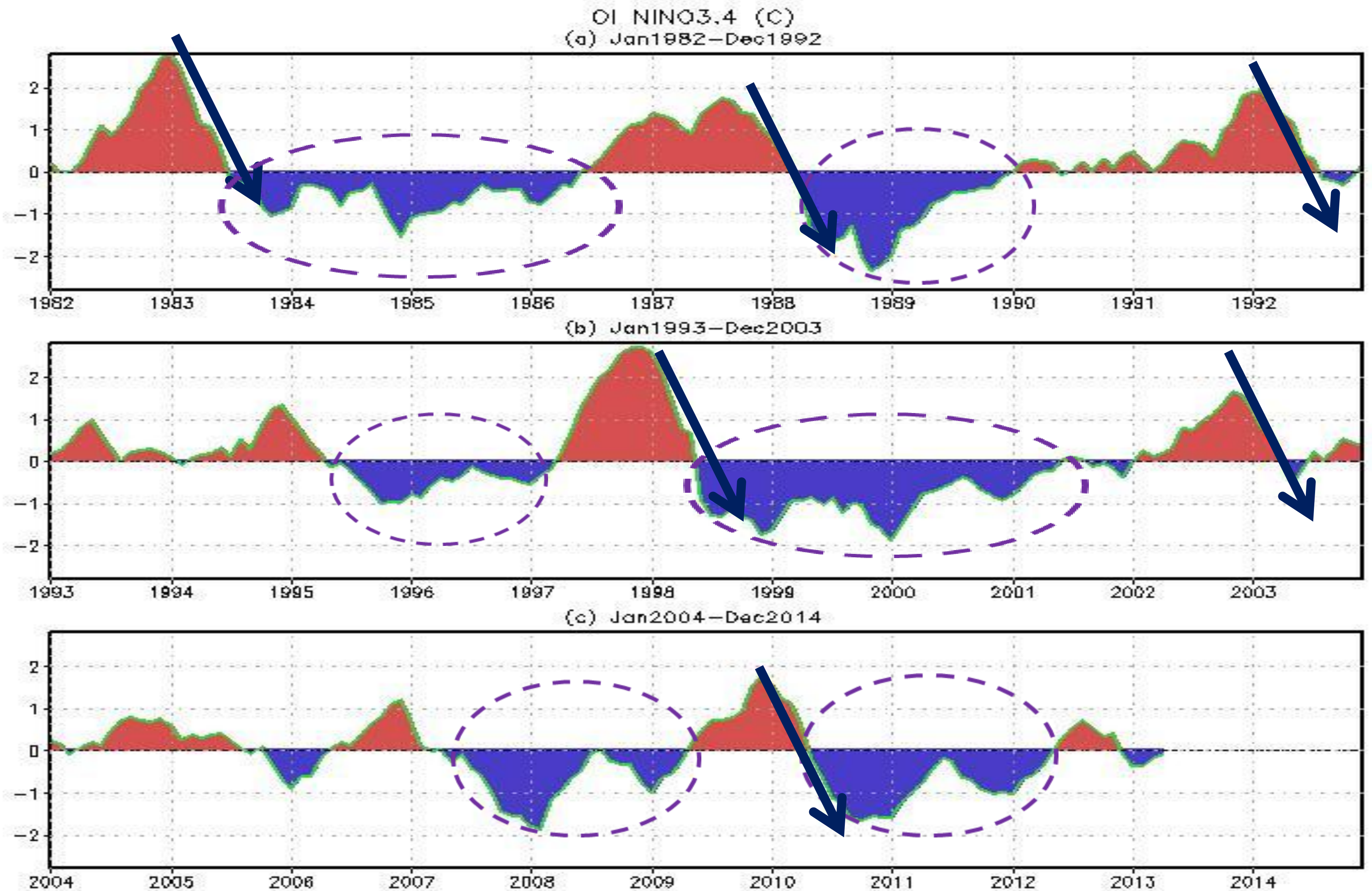
38th CDPW, College park, MD, Oct 21-24, 2013

Observational Evidence: Most La Ninas are followed by another La Nina or weak negative SSTA



Unlike El Nino, almost no La Nina event decays straight down.



DJF Nino3.4 SSTA in the peak years and the following years

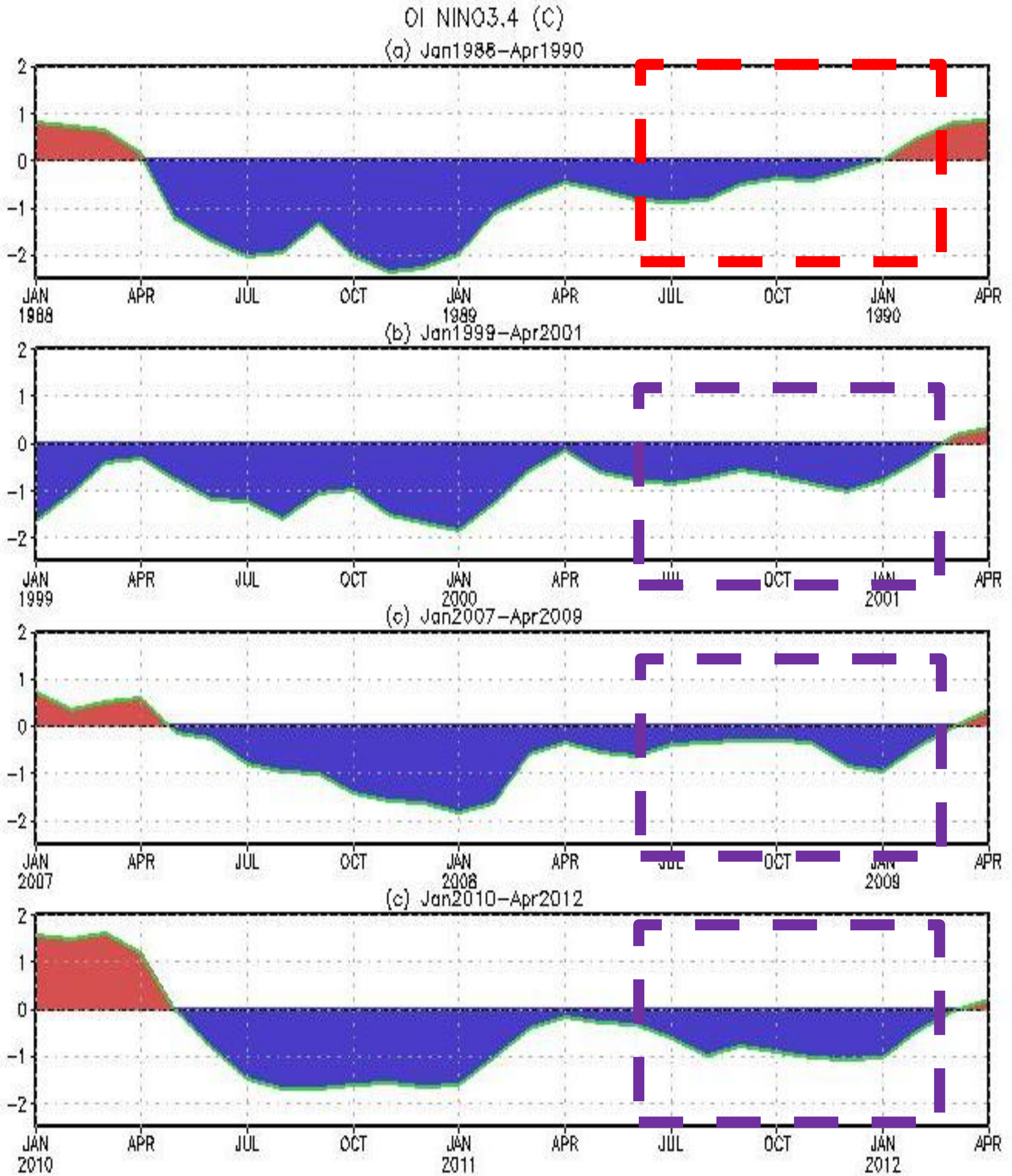
(http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml).

peak year & DJF SSTA		following year & DJF SSTA
1984/85 (-1.0ºC)	√	1985/86 (-0.5ºC) No second year La Nina
1988/89 (-1.7ºC) Major La Nina	×	1989/90 (0.1ºC) No second year La Nina
1995/96 (-0.9ºC)	√	1996/97 (-0.5ºC) No second year La Nina
1999/2000 (-1.7ºC) Major La Nina	√	2000/01 (-0.7ºC) Second year La Nina
2005/06 (-0.9 ºC)	×	2006/07 (0.7ºC) No second year La Nina
2007/08 (-1.5ºC) Major La Nina	√	2008/09 (-0.9ºC) Second year La Nina
2010/11 (-1.4ºC) Major La Nina	√	2011/12 (-0.9ºC) Second year La Nina

For example, 1999-2001 and 2007-2009, 2010-2012 La Ninas were followed by weak La Ninas;

But 1988-1990 La Nina did not.

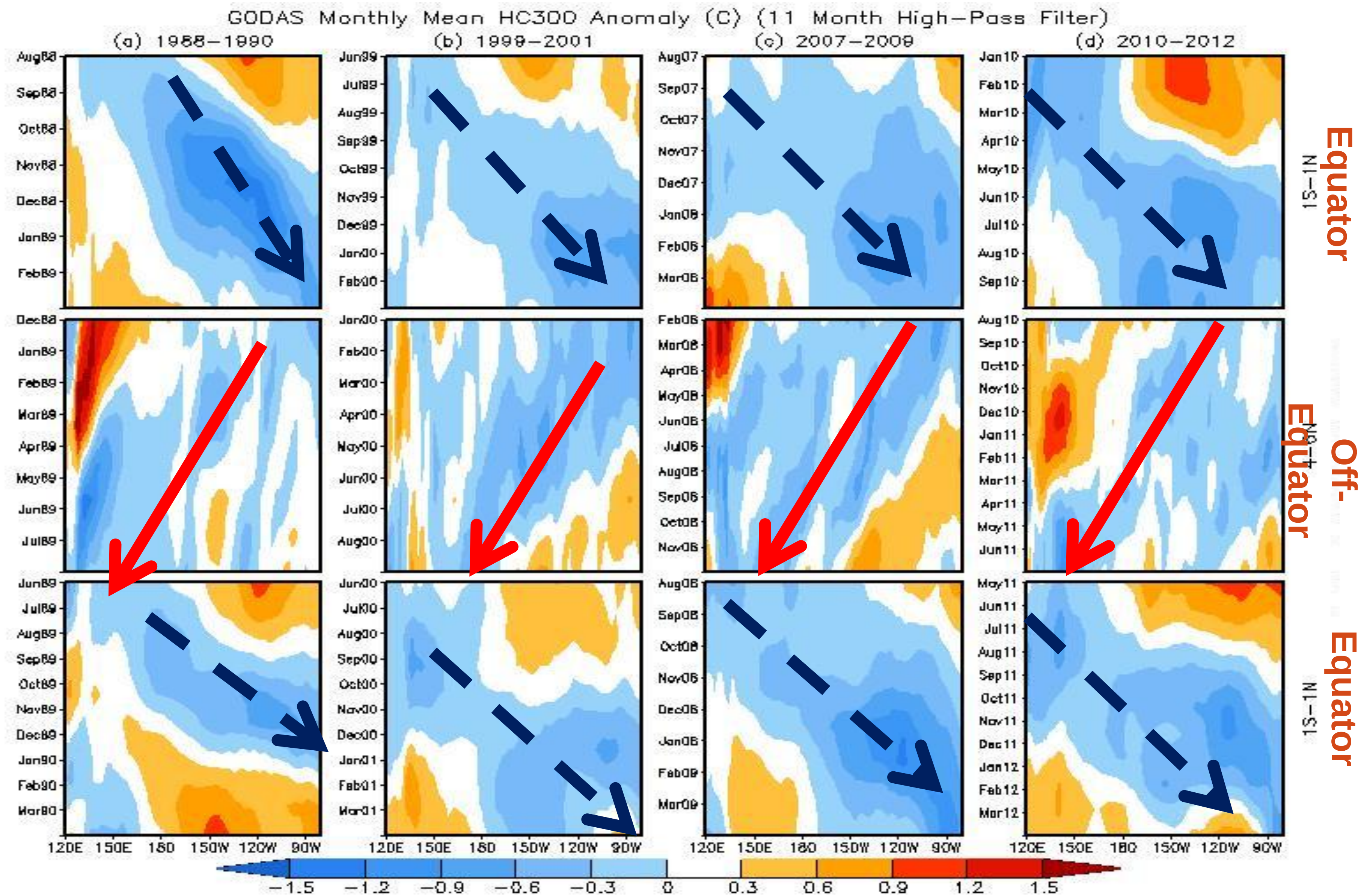
The weak La Ninas occur in second winter following the major La Nina, showing seasonal phase locking.



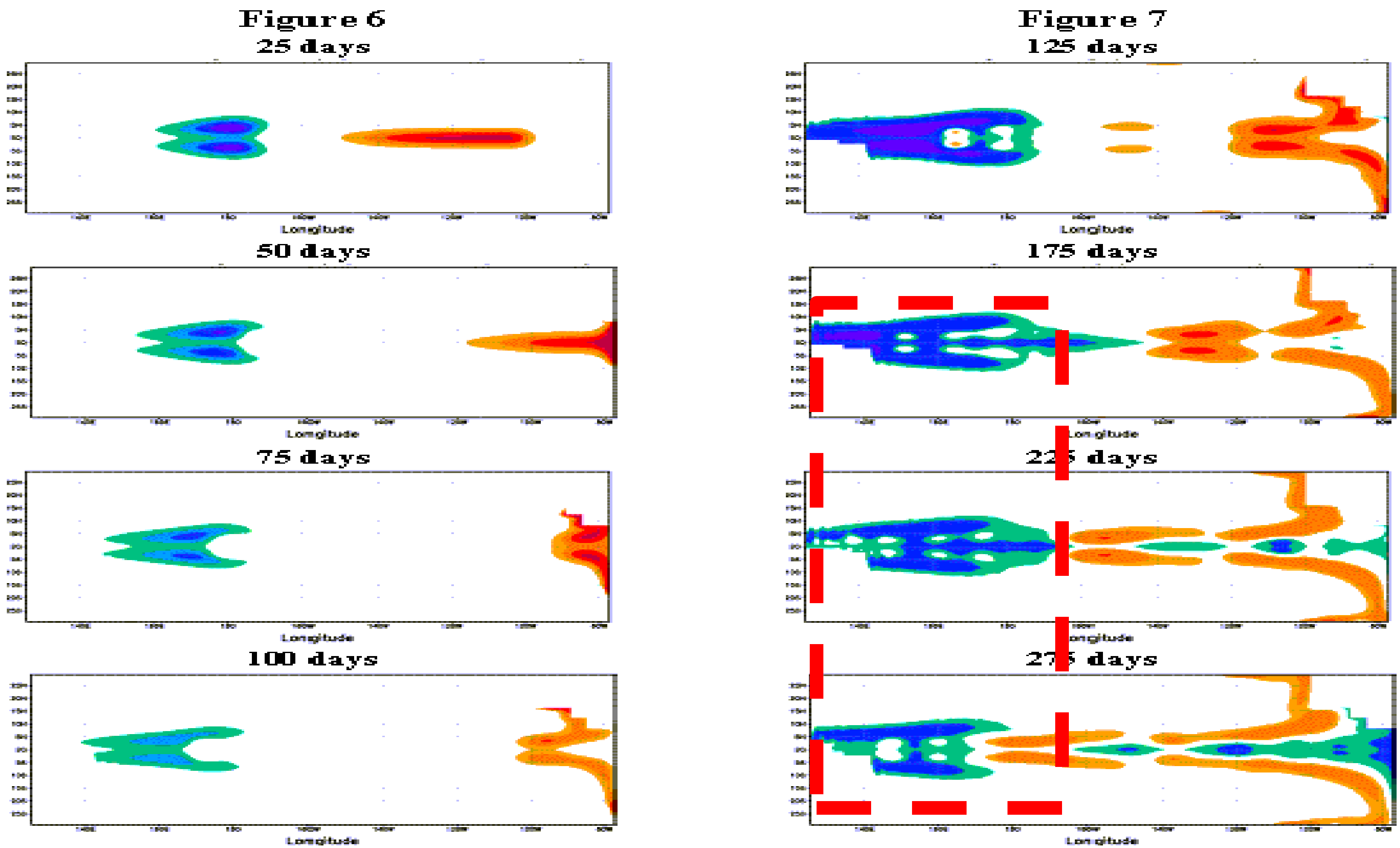
So, a precondition of occurrence of multi-year La Nina seems that La Nina must be a strong event.

Why?

HC300 propagation along equator and off-equator:4 Strong La Ninas



The observed propagation and reflection of HC300 generally follow the delayed oscillator theory in the first half, but differ in the second half



(From IRI: http://orca.rsmas.miami.edu/~melicie/dmodel1.htm)

(1) Below normal HC300 associated with La Nina propagates eastward along equator;

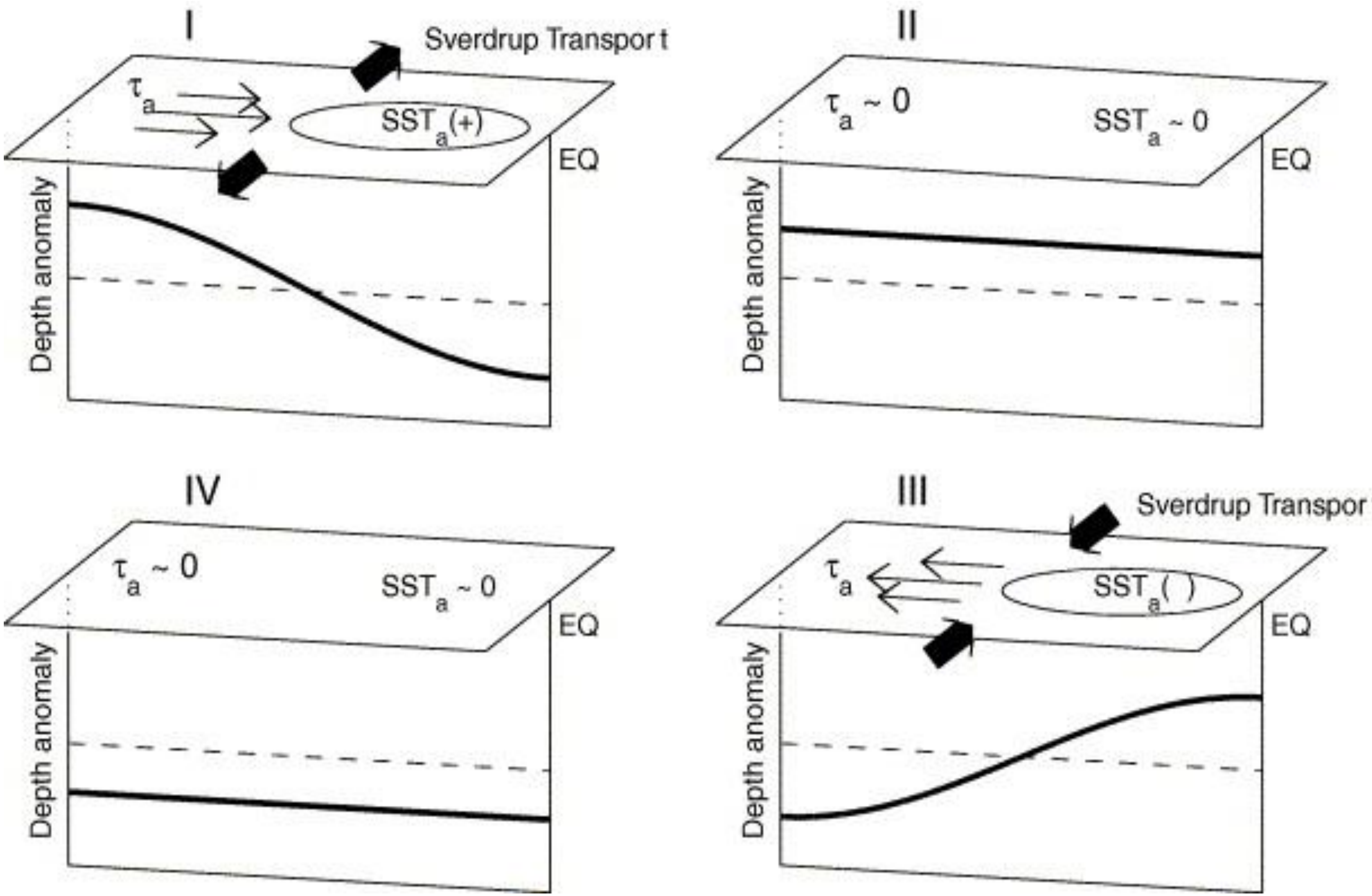
(2) Then it is reflected in the east boundary and propagates westward along the off-equator in both hemispheres;

(3) Late, negative HC300 is enhanced along the equator and propagates eastward, forming the follow-up (second-year) La Nina.

These HC300 evolution features are similar for both strong and weak first-year La Nina, although the signal is stronger and the propagation is clearer for strong La Nina than for weak one.

Why multi-year La Nina is more often than multi-year El Nino?

Phase I: Discharge process: *Equator to off-Equator*
Phase III: Recharge process: *off-Equator to Equator*



Wang, C., and P. Fiedler**, 2006:** **ENSO variability and the eastern tropical Pacific: A review. *Prog. Oceanogr*. 69, 239–266**.

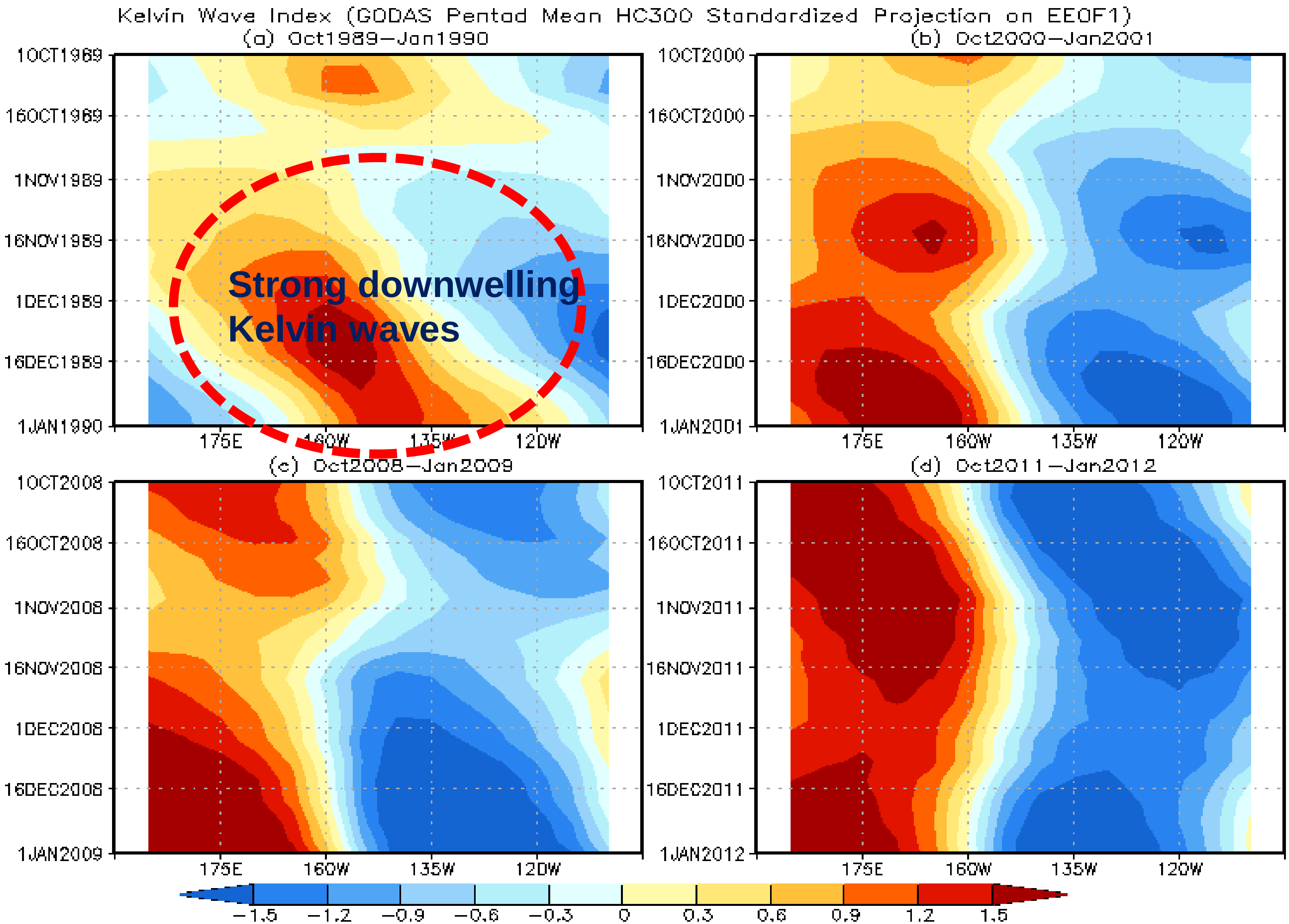
What is the impact of the reflected HC300 along the off-equator on ENSO cycle?

(1) Westward propagating of the reflected HC300 along the off-equator in both hemispheres interrupts the recharge process;
(2) The interrupted recharge process prevents El Nino development, may lead to a follow-up La Nina developed.

Then, we have to ask why some major La Ninas are followed and not followed by another La Nina?

That is because of the Kelvin wave differences.

Kelvin wave activity differences



Why some major La Ninas are followed and not followed by another La Nina?

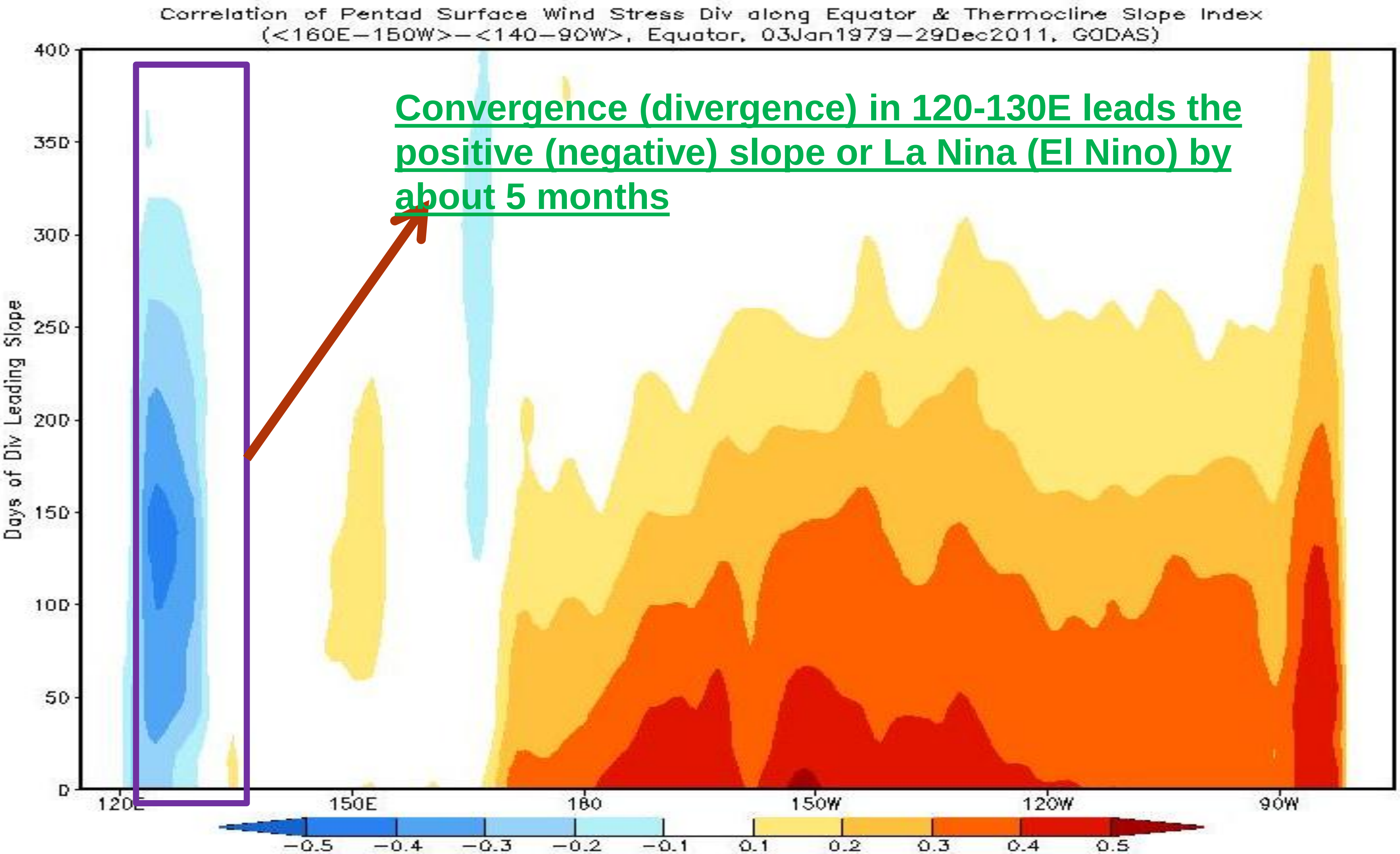
That is because of the Kelvin wave differences.

What cause the Kelvin wave differences?

It may be the surface wind anomaly in the western Pacific.

slope index:

Surface wind stress divergence along Equator connected with thermocline slope (D20: <160E-150W>-<90-140W>, Pentad GODAS): Precedent signal around 120-130E along the equator



Divergence of GODAS pentad surface wind stress anomalies averaged 120-130E, 2S-2N

Strong convergence (weak convergence/divergence) is connected with follow-up (not follow-up) La Nina cases

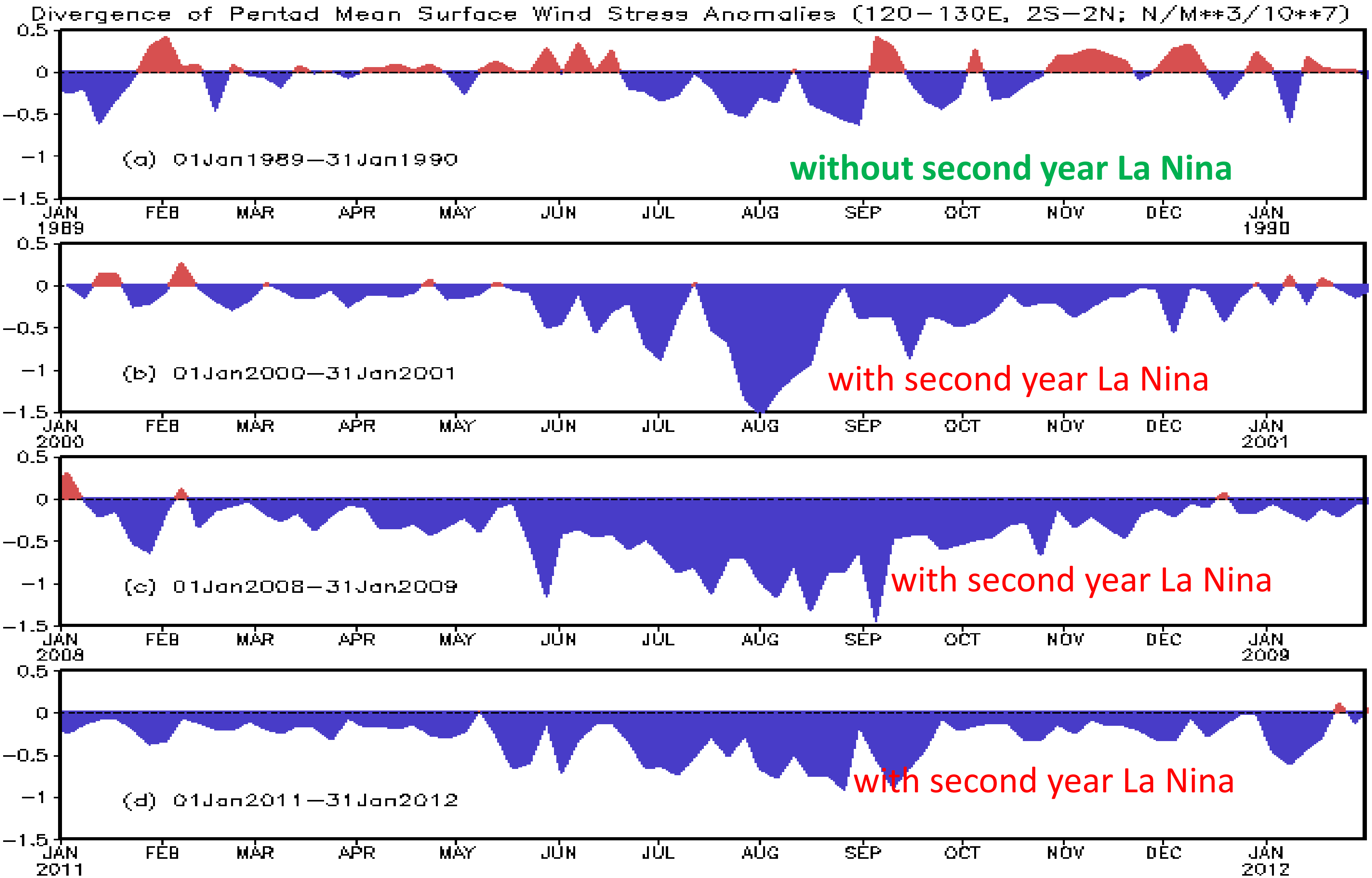
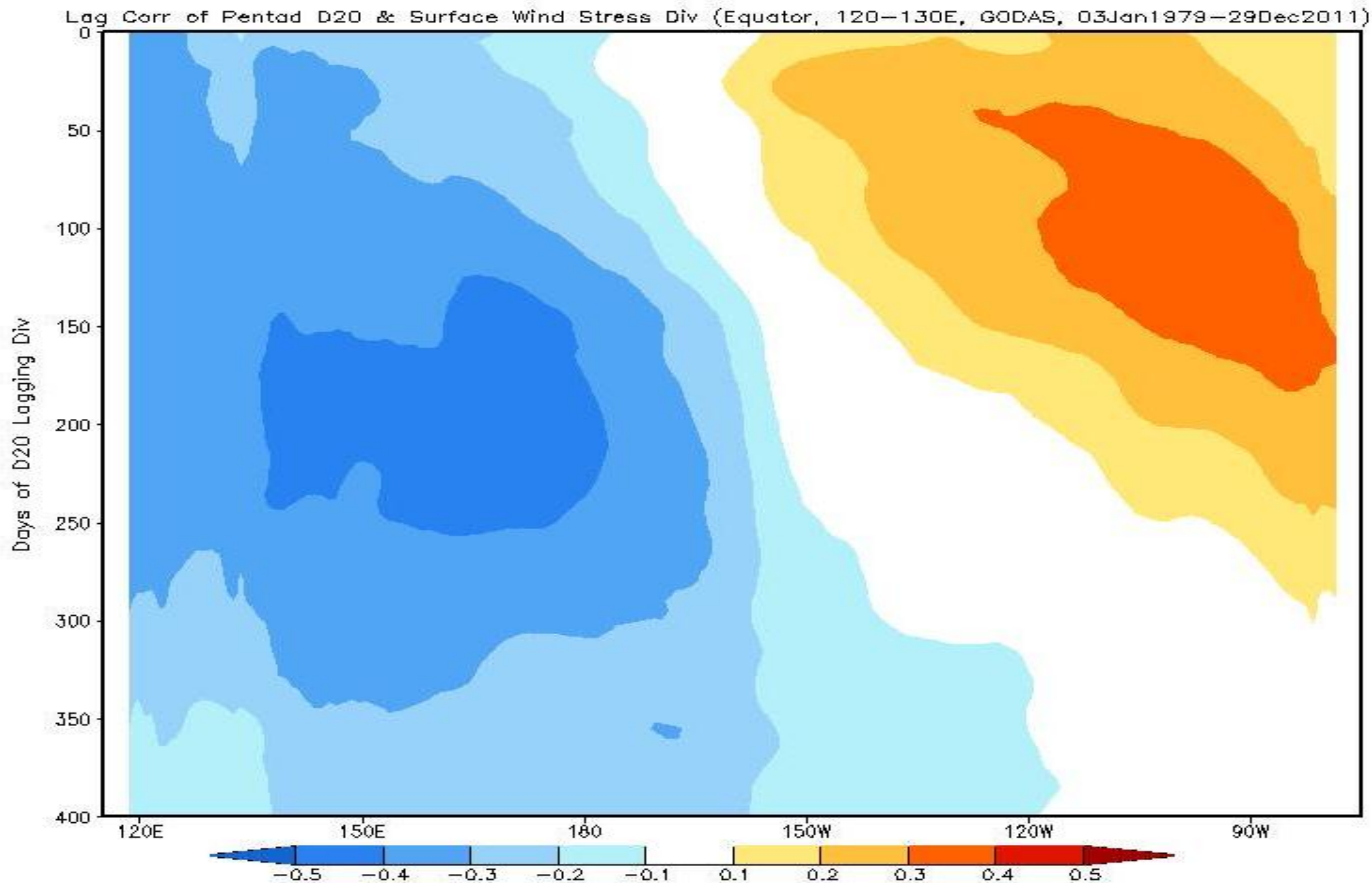


Fig. 5

Correlation of pentad D20 with divergence of pentad surface wind stress anomalies averaged (120-130E, 2S-2N): **The divergence (convergence) is tied up with El Nino (La Nina)**



Why were some La Ninas followed by another La Nina?

Following factors may determine whether there will be a following–up La Nina:

- **One precondition is that it is a strong La Nina:** Large negative heat content anomalies associated with strong La Nina propagate eastward as Equatorial cold Kelvin wave, then are reflected in the east boundary as cold Rossby waves in the tropical N/S Pacific. Large anomalies insure the reflected signals strong enough.
- **Interrupted recharge process:** The westward propagating negative heat content anomaly interrupts the recharge process after the peak of major La Nina, and prevents the formation of El Nino, sometime may generate a follow-up La Nina.
- **Eastward propagating warm Kelvin waves: Strong (weak) eastward propagating warm Kelvin waves may make the following-up La Nina died young (formed).**
- **Weather noise: Strong westerly wind anomaly and its associated divergence along the equatorial western Pacific (120-130E) may trigger strong warm Kelvin wave. That may be a reason causing large uncertainty of model prediction for follow-up La Nina.**

What factors control the long-persistent surface wind divergence and convergence in the far-western Pacific?

Don't know!

More Information

Hu, Z.-Z., A. Kumar, Y. Xue, and B. Jha, 2013: Why were some La Niñas followed by another La Niña? *Clim. Dyn.* (published online). DOI: 10.1007/s00382-013-1917-3

Comments or ask PDF files, send mail or e-mail to

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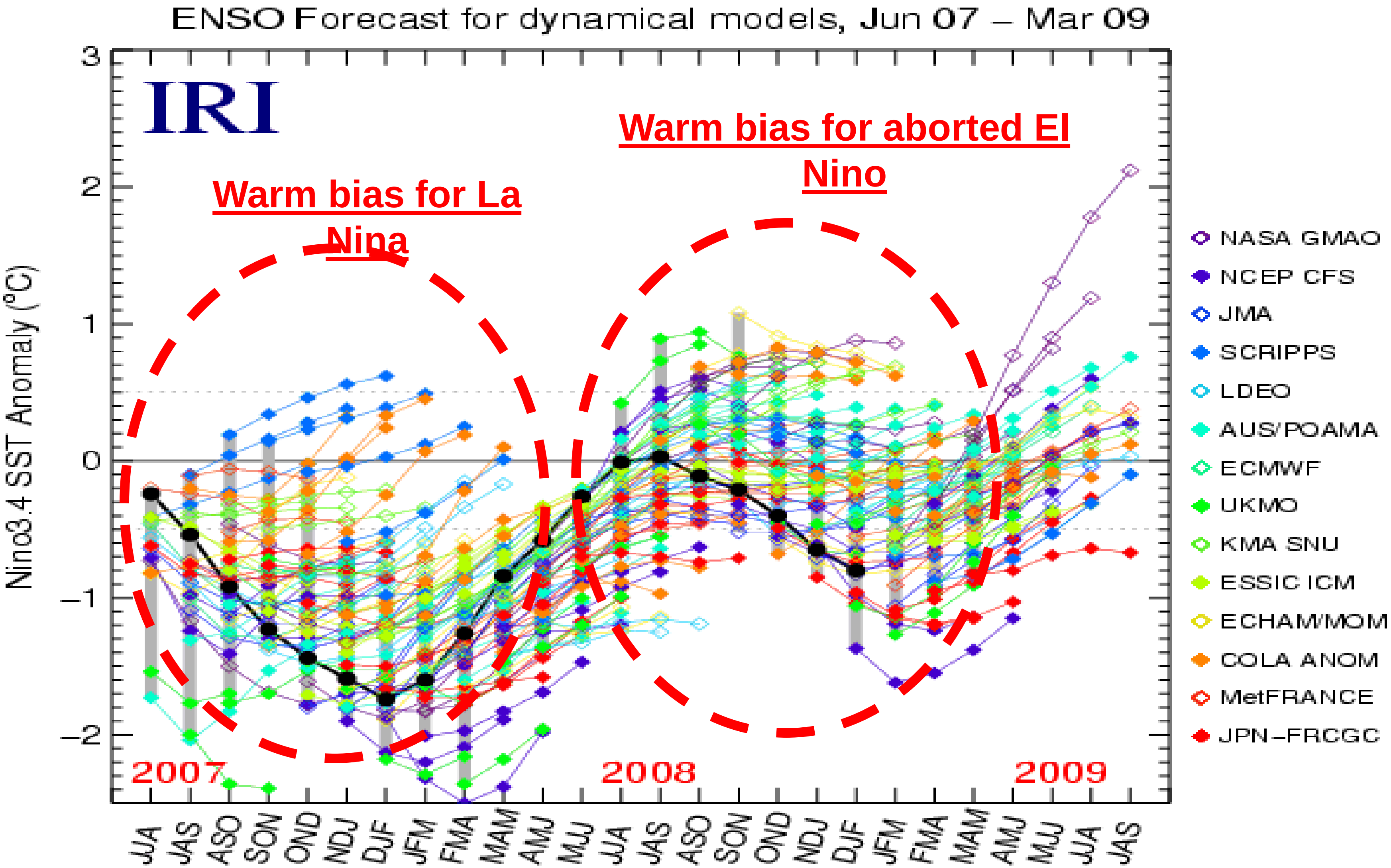
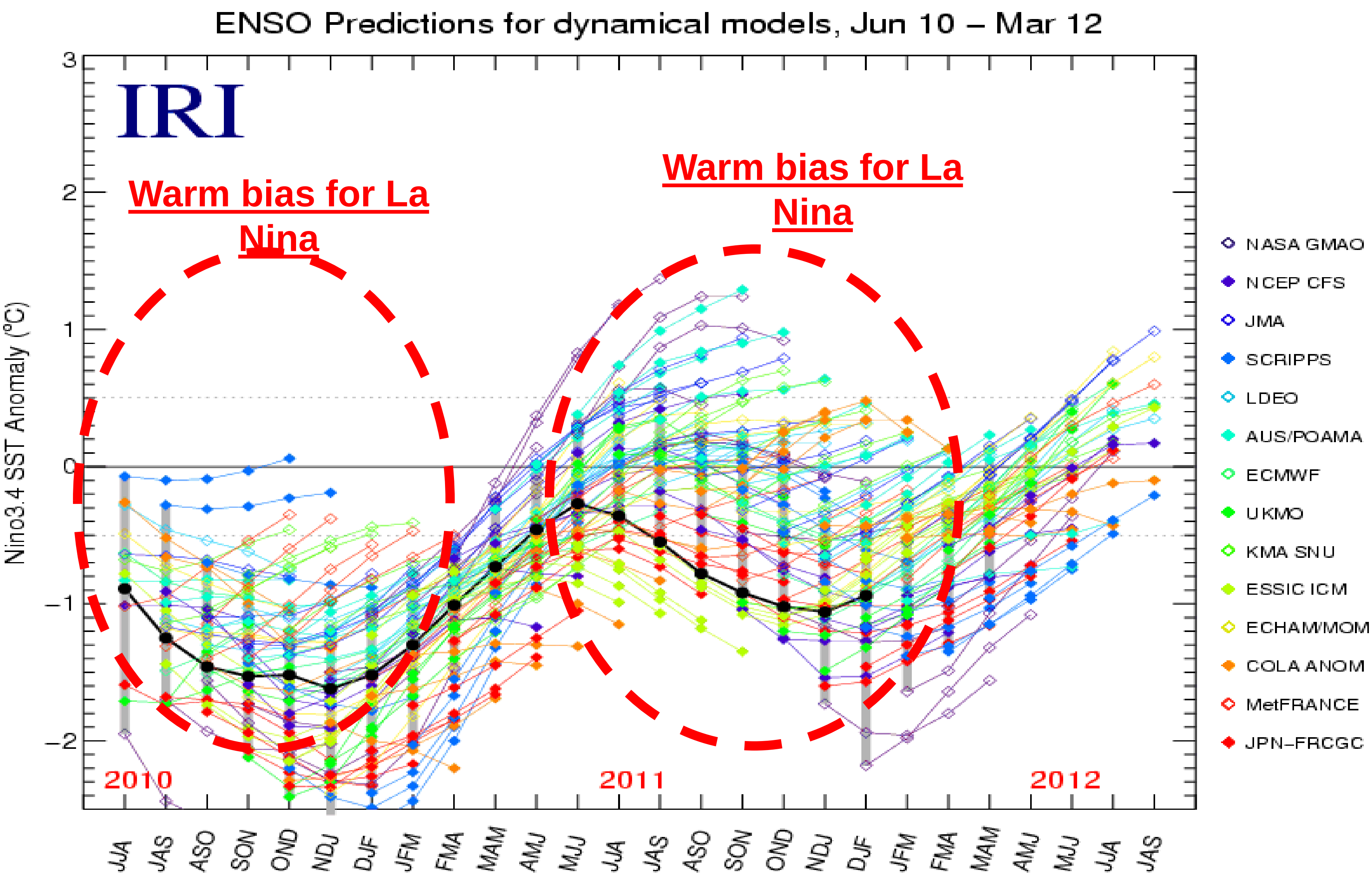
All Model Forecasts 2007-2009 La Ninas



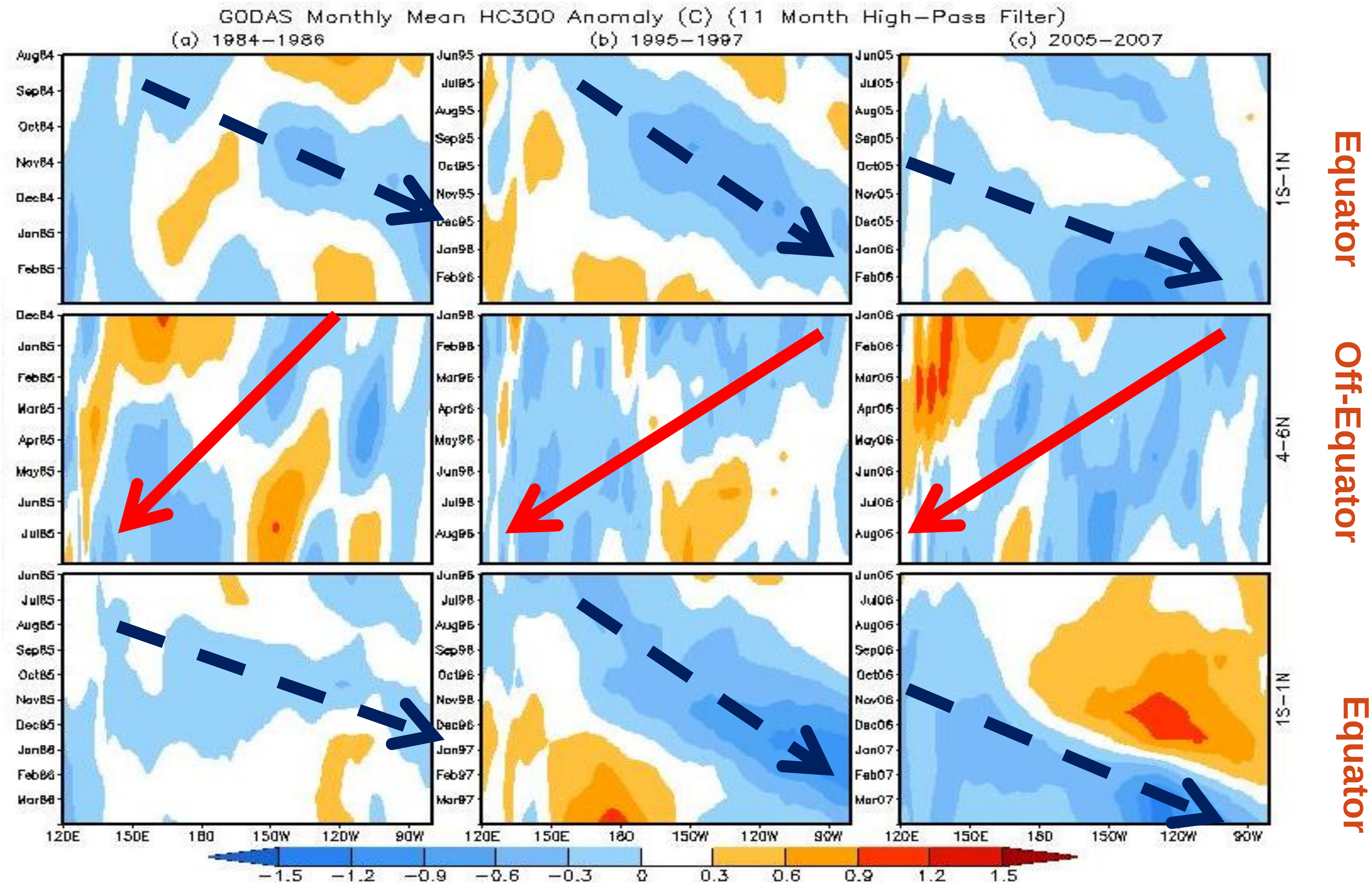
- **Models face challenges to predict ENSO cycle in the last a few years.**

All Model Forecasts 2010-2012 ENSO Cycle

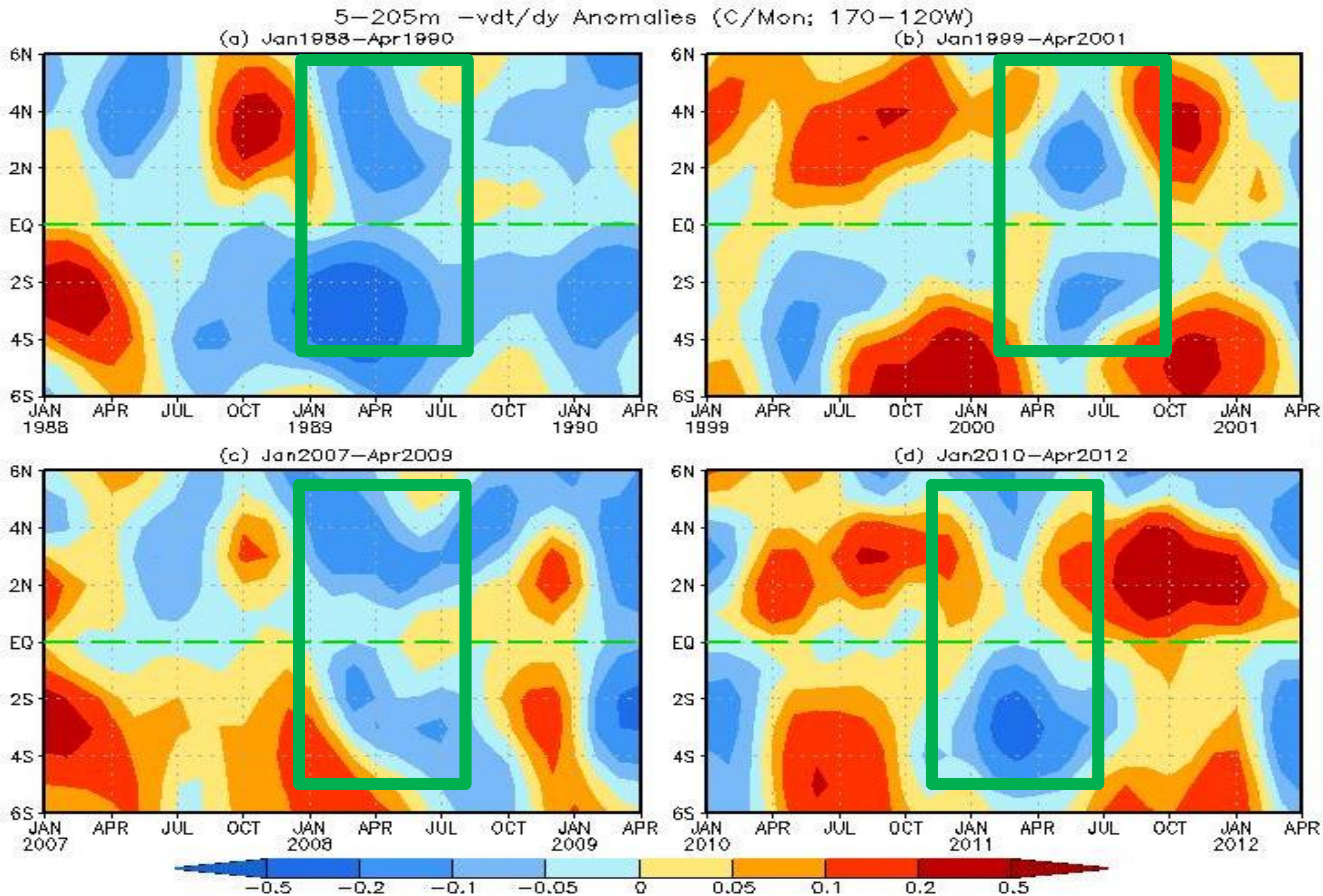


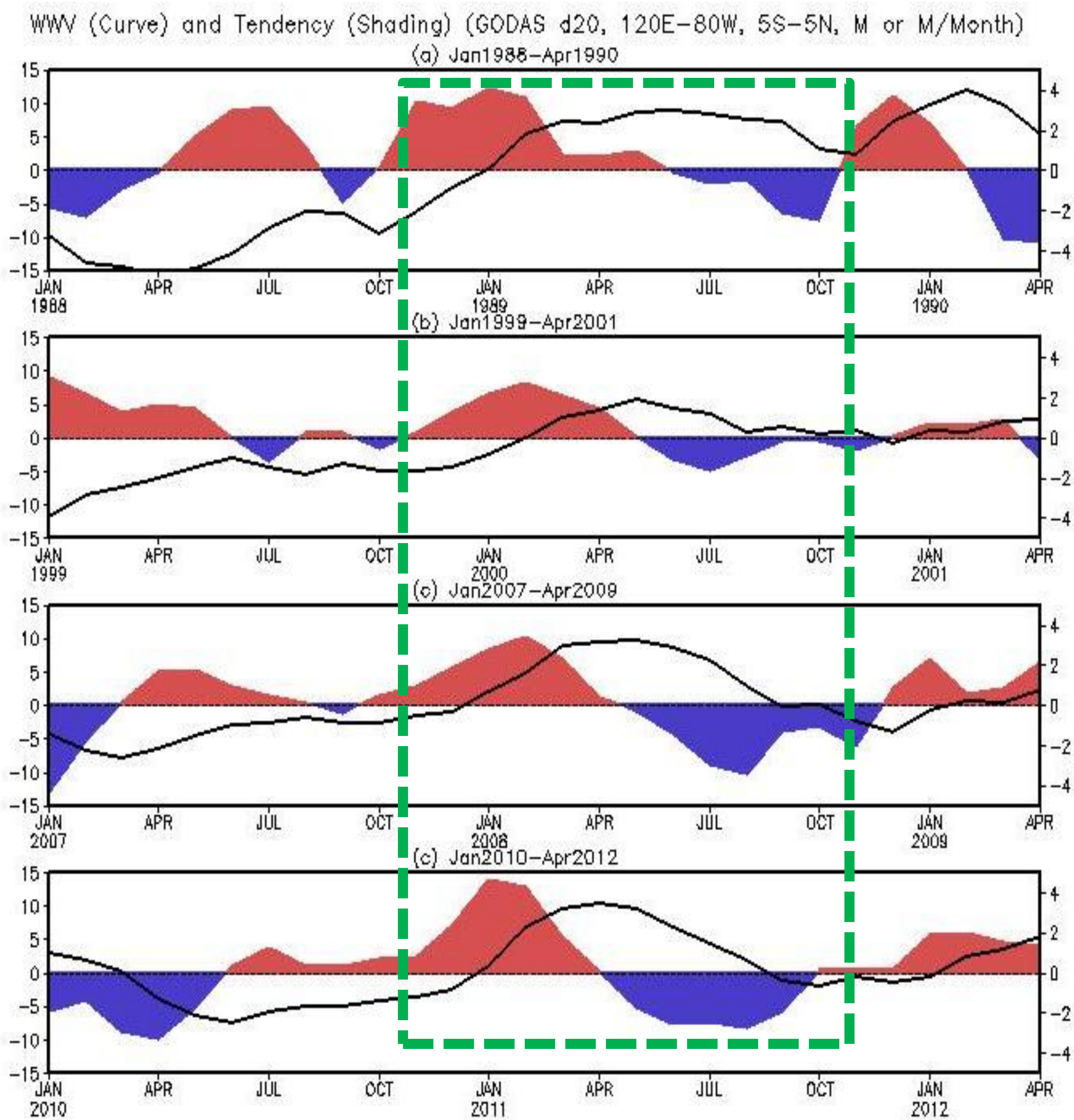
- Models face challenges to predict ENSO cycle in the last 2 years.

HC300 propagation along equator and off-equator: 3 Weak La Ninas



–vdt/dy (5-205m, 170-120W): Meridional advection causes cooling after the major La Nina





During/after a major La Nina, the recharge process is interrupted by the westward propagation of negative heat content along the off-equator, due to the convergence from the off-equator to the equator.

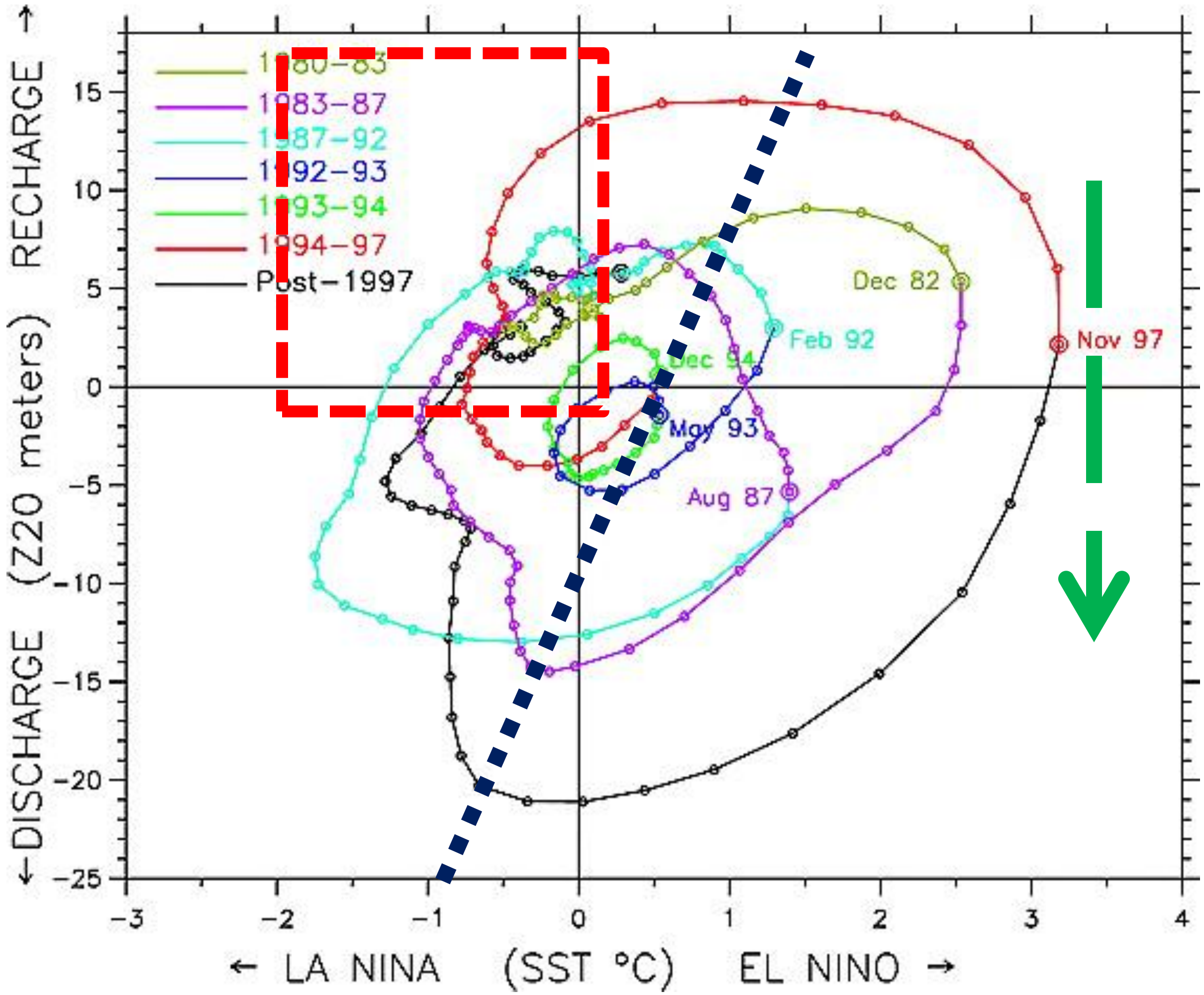
The interrupted recharge process prevents formation of El Nino, may lead to a follow-up La Nina developed.

Asymmetric feature of ENSO cycle:

El Nino is normally followed by La Nina

but La Nina is only sometime followed by El Nino

The recharge process is less effective after La Nina, why?



Phase orbits of Nino3.4 (x-axis), and D20 (y-axis) with the scales chosen so that a given distance in either direction represents an equal fraction of variance. Small dots are drawn at the center of each month. The line color changes at the peak of each El Niño SST maximum, which is also shown as a large dot and its date is labeled. The final point is May 2002, noted with a large black dot.

Kessler, W. S., 2002: Is ENSO a cycle or a series of events? *Geophys. Res. Lett*., **29(23)**, 2125. DOI: 10.1029/2002GL015924.

Kelvin wave differences: Wind stress and OLR anomalies along the equator

(a) Strong eastward propagating warm Kelvin waves present for the case not followed by La Nina
(b) The Kelvin wave seems triggered by the eastward propagating convection initiated in 120-130E.
(c) The warm Kelvin wave kills the cooling in the eastern Pacific and aborts the follow-up La Nina

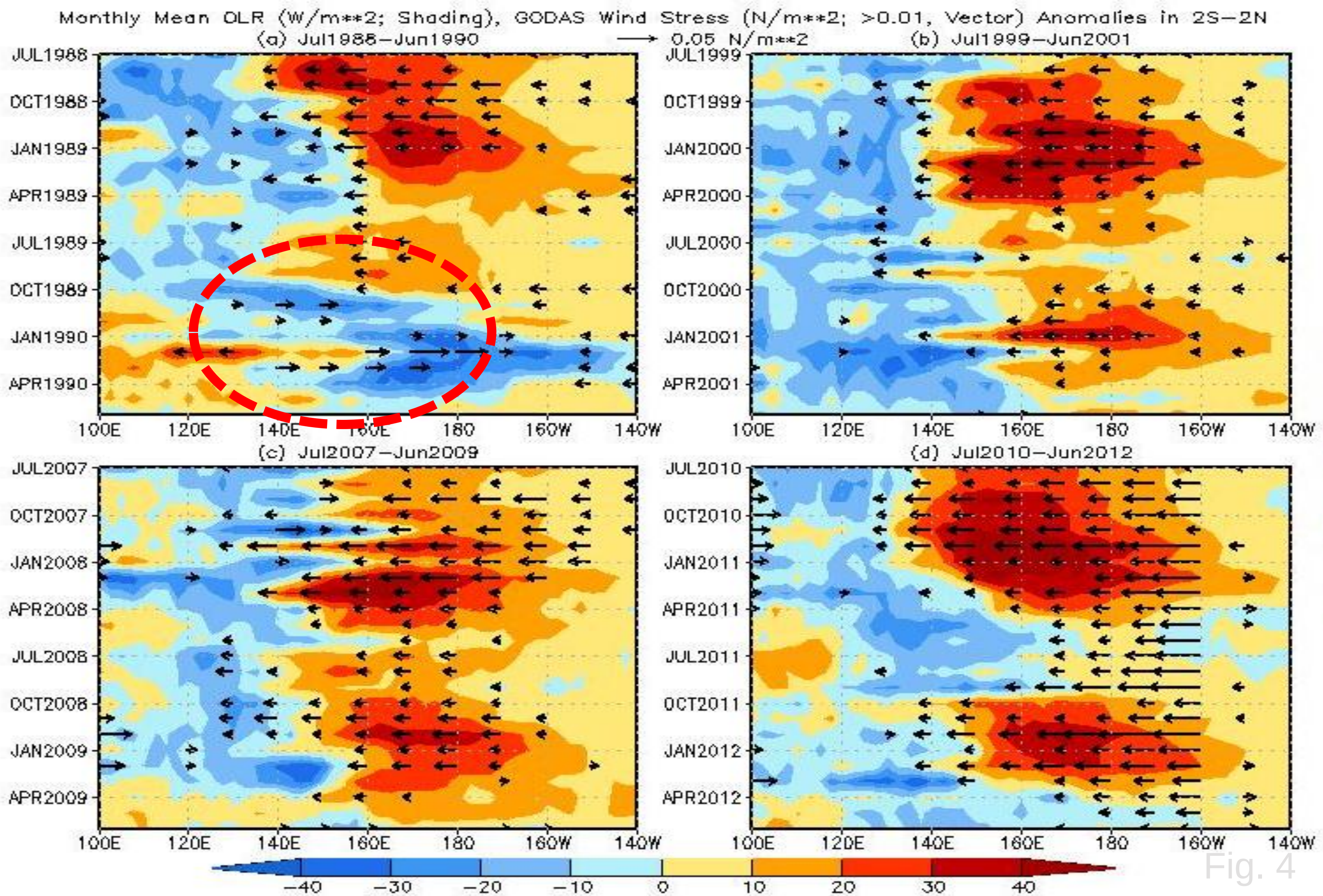
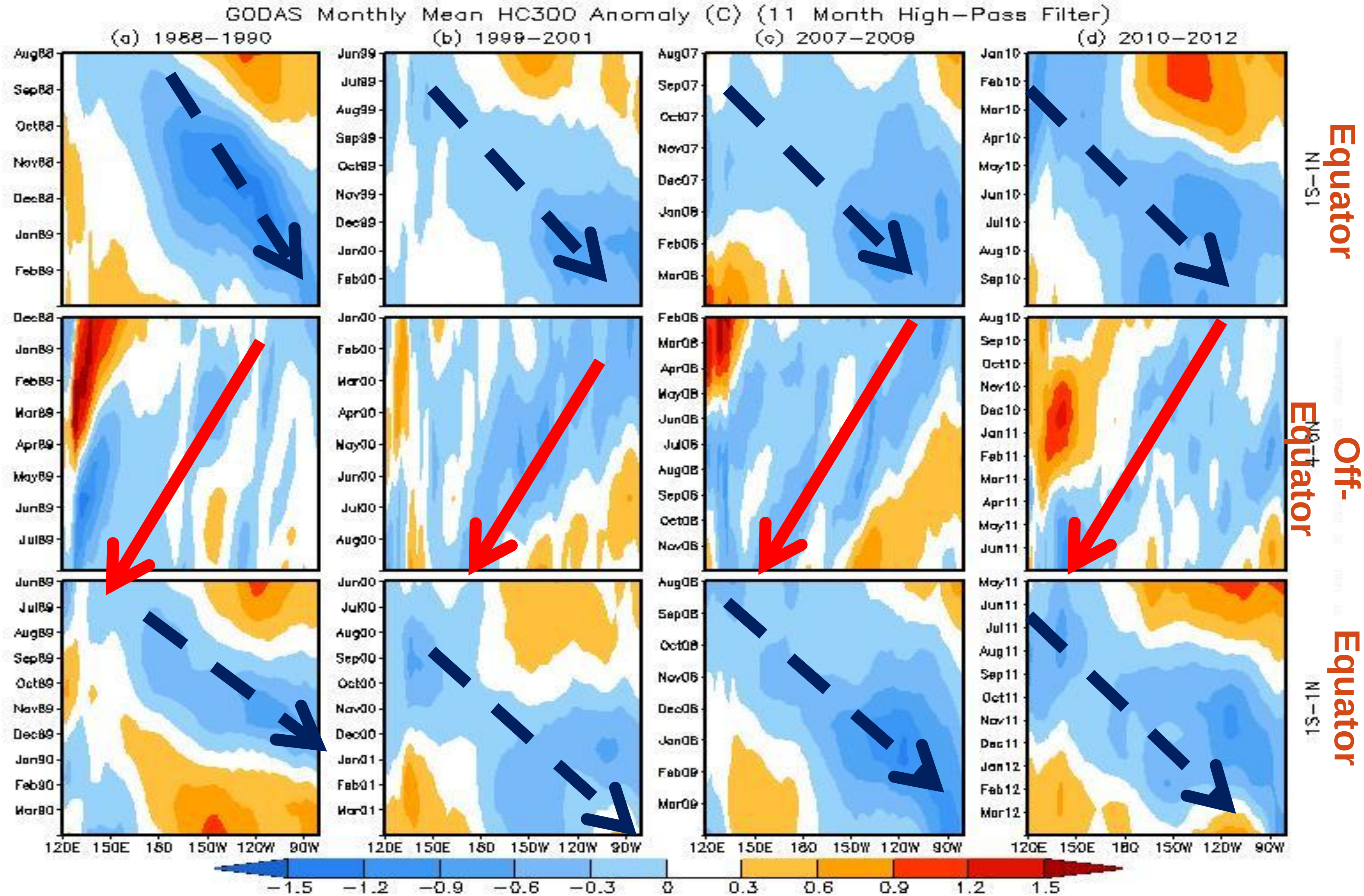


Fig. 4

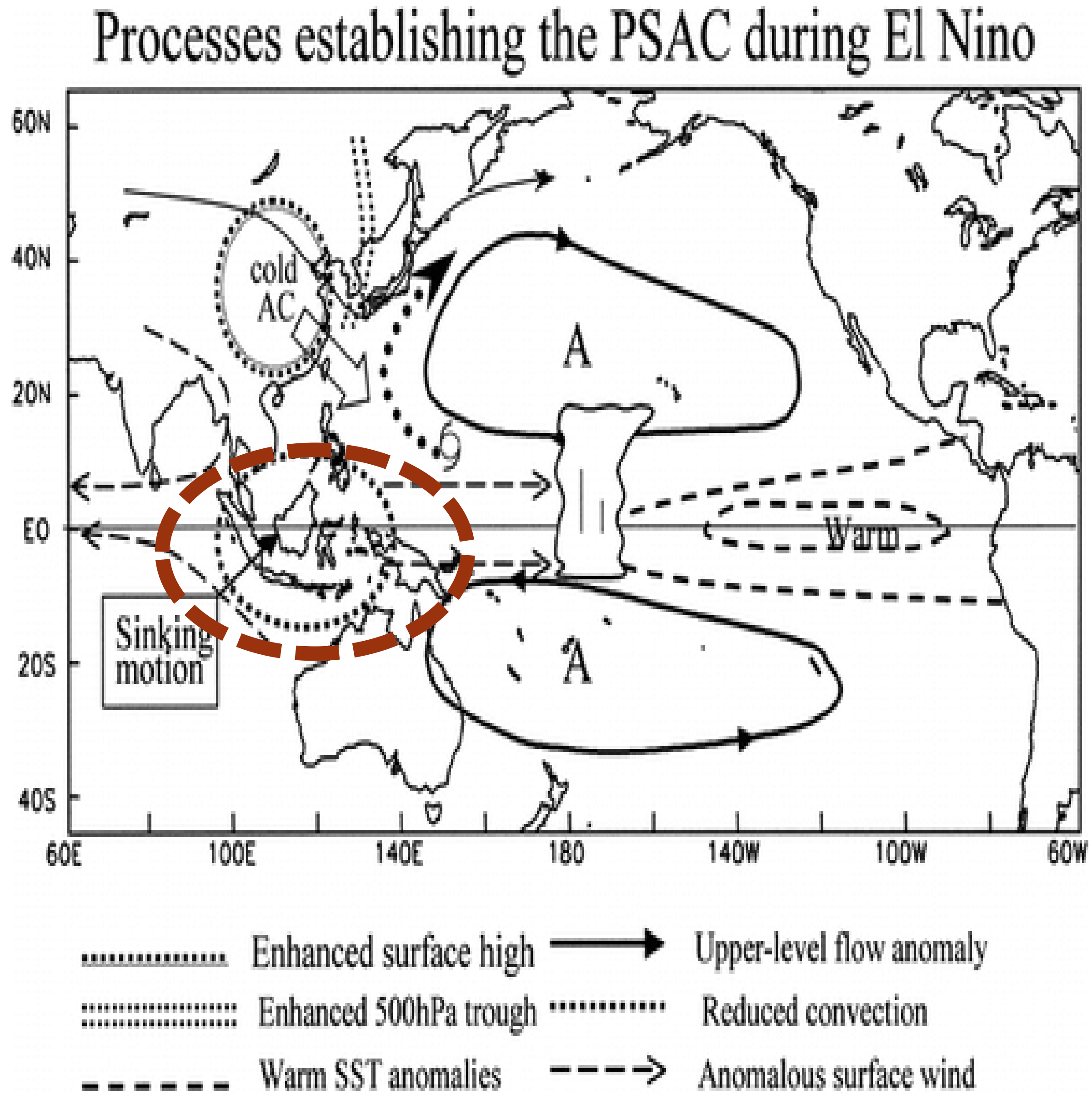
HC300 propagation along equator and off-equator: 4 Strong La Ninas



Our results are consistent with Wang and Zhang (2002) about the connection of ENSO and Philippine High.

However, we suggest that the Philippine Sea Anti-Cyclone (PSAC)-associated divergence/convergence may trigger ENSO;

But, Wang and Zhang (2002) argued that the development of the Philippine Sea anticyclone is attributed to combined effects of the remote El Niño forcing, tropical-extratropical interaction, and monsoon-ocean interaction.



Wang, B., and Q. Zhang, 2002: Pacific-East Asian teleconnection, part II: How the Philippine Sea anticyclone established during development of El Nino. J. Climate, 15, 3252-3265.